Industrial Efficiency from the Psychological Standpoint.

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(A Series of Four Lectures delivered at the Imperial College of Science and Technology.)

Lecture I.

DR. MYERS said there were four main determinants of industrial efficiency: first, the mechanical; secondly, the physiological; thirdly, the psychological; and, fourthly, the social and economic. Of these the psychological was by far the most prominent and fundamental. "Intelligence" in improving mechanical conditions, and a sympathetic "understanding" of the standpoint of others were far more important than capital or labour. The physiological factor of muscular fatigue was now fast becoming generally negligible in industry, compared with the effects of "mental" and "nervous" fatigue and of weariness, want of interest, suspicion, hostility, etc. In the present series of four lectures, therefore, the psychological factor would be the main consideration, and he (the lecturer) would endeavour to show its importance in (1) movement study; (2) fatigue study; (3) selection study; and (4) incentives study. In movement study it would be necessary also to take into consideration mechanical and physiological factors; in fatigue study physiological factors; in studying the selection of workers according to their special aptitudes, the standpoint would be principally psychological; in studying the incentives towards increased efficiency, social and economic considerations would have to be introduced.

Movement study, the subject of the present lecture, might be regarded from four aspects. The first of these was the planning of the factory or business. The second was the arrangement of tools and material. The third was the division of work among skilled and unskilled employees. And the fourth was the learning of the best methods of work.

The planning of the factory involved, amongst other things, the proper organisation of administrative departments for specification, timing, costing, order of work, instruction, material, and stores, and the proper location of the different industrial operations. Into that particular subject it was not the lecturer's intention—indeed, it was beyond his capacity—to enter. He would, however, quote a few striking instances where industrial efficiency had been improved by a better arrangement of tools and materials. The New England Butt Company, for example, was engaged in manufacturing machines for braiding called braiders, and Mr. F. B. Gilbreth was called in to apply movement study to the factory. He found the tools lying anywhere, the base of each braider placed on an ordinary low bench, with the various parts kept on the floor or in boxes. No special method was being taught. The assemblers worked by tradition, or according to individual fancy. Mr. Gilbreth studied the best positions for the tools and parts before assembly. The latter he arranged in definite order on a vertical trellis frame called a "packet," which he provided with hooks and arms, so as to allow the parts to be placed in the most convenient position for the assembler's grasp. This packet was loaded by an apprentice, who was being trained in the principles of assembly. The tools were henceforth placed in pre-arranged order on the table, and the table was so designed by Mr. Gilbreth that it could be also used when turned over on its side, thus providing a table of two heights, one for ordinary, the other for the taller or "double-deck" braiders.

BRAIDING MACHINE WITH ADJUSTMENTS BY MR. GILBRETH.

The result of these improvements was that without increased fatigue, and with increased earnings a man could assemble 66 braiders per day, in place of a previous output of 18 per day, that is to say, a 266 per cent. increase in rate of output.

Another instance of the effects of movement study occurred in a certain British foundry which was engaged in making Mills grenades and what are called "fuse hole plugs." These fuse hole plugs fit into the top of shells in place of the fuse until they are wanted to be actually used. The managing director of the foundry came to the conclusion that he could improve the output enormously without involving a greater amount of fatigue to the workers, and he set to work, with one or two men whom he could trust, including his works manager, to time each small job in his and their cases, to analyse that job into its essential component movements, to time these movements with a stop-watch to see how he could improve the movements. Having done that to his satisfaction, and having written a list of the times of each separate unit movement and the time in which the whole job should be performed, and calling that the standard time, he devised instruction cards into which these estimates were put. He deducted 10 per cent. from what he had evolved as a standard time to allow the worker 45 minutes during the day to attend to his personal needs, and also to allow for accidental waste of time; and then, after making various improvements in the arrangement of materials, in the efficiency of the machining, and in the co-ordination of the on the one just mentioned over three years. Two is a short time to solve a real big problem. Now from what has been said it will be seen that the changing of an executive in charge of a problem, unless he proves himself radically unfit, simply because he does not arrive at the solution immediately, is a grave mistake. The executive has this problem before him night and day and the constant excitation of this part of his brain is producing a slow but nevertheless sure development which, if the problem is not impossible, must lead in time to its solution. Now if constant changes are made among the men in charge the new man has to go through all his predecessor went through before he has reached the same mental development. If then other changes are made the foregoing is repeated and the management has nothing to its credit but a large experimental expense. The management should be careful in choosing the man who is put in charge, but having chosen a man it should continue this man on this problem until results are achieved or until it has made up its mind that a successful solution will not pay dividends on the amount of money required for its solution. As mills go, far too many problems are abandoned before a fair trial has been given, owing to the non-observance of these principles.

I have spoken here of the mental attitude of the executive in charge of the successful solution of a problem and laid down the principle that he should be a believer in its successful solution from the start, and now I want to say one word as to the attitude of the management in regard to suggestions coming from those responsible to it. It must be constantly borne in mind that the management puts its capital in these operations and that it will suffer for all mistakes it makes as well as the mistakes of its employees, and that consequently its decision should be final, good or bad. But it often happens that it can reap benefit from the mistakes it makes as well as penalties. The wise management will allow certain leeway (within certain limits) to its chief executives, as they, after all, carry out the policy of the management.

For instance, a foreman may come to the executive with a proposition which that executive knows from past experience will not work. He may turn it down absolutely or he may consider, after figuring it over, that he will allow the foreman to try it and fail and convince himself. I have done this many times myself and have obtained results from the changed mental attitude of the men which far outweighed the small expense involved, and sometimes I have seen how to make suggestions from the failure which may change the failure into more or less of a success. In case of foreordained failure, so to speak, I always put it up to the man himself and give him my heartiest support, so that when it fails he can have no comeback. If, as sometimes happens, the management is mistaken and the man gets the solution, the executive should not be grudging of his acknowledgment, but take off his hat to him, so to speak, in a whole-hearted manner. This tends to produce not only co-ordination but co-operation and the *esprit de corps* which we are striving to obtain.

Joint Management System in Germany.

An article in *Weltwirtschaftsdienst* on the so-called "joint" management of industrial establishments (*gemeinwirtschaftlicher Betrieb*), points out that the guiding principle of such a system has been stated to be administration by autonomous bodies under Imperial supervision. The first domain into which the system is to be introduced is that of coal mining, and the potash mines will be similarly managed as soon as possible. Joint management in the coal mining industry is represented as a general and comprehensive compulsory syndication under Imperial control and with the co-operation of the employers and consumers. There is no question at the moment of nationalising coal mining or even of the coal syndicate, the whole scheme being merely an outline to be filled in later by Government after consultation with a council of experts. Moreover, the employers are still to participate in the administration of industrial concerns, and this participation, based on the principles of councils of the industrial concerns, is to lead to a constitutional structure on a democratic foundation.

Up to the present only guiding principles have been laid down, and advocates both of the old and new system will find them difficult to accept or to criticise. It is impossible to make much of the dictum "Every German must employ his intellectual and physical strength in the manner demanded by the welfare of the community," when it is quite uncertain how the principle is to be carried out in practice. It is clear that a nation like Germany, so deeply in debt and so disorganised, demands a certain obligation to work and a stringent economy of labour, and in future no individual can be allowed, as heretofore, to produce what he wishes and how he wishes, and to employ the economic resources of the nation at will and possibly to waste them. But, on the other hand, it would be a great error to rob private initiative of free play and confine the entire economic system within arbitrary limits. Organisation and systematic management may increase economic efficiency if they are suitably adapted to the inner forces and needs of human nature and the economic life, but they may also reduce the effective degree of production by inertia and bureaucratic checks, and it is precisely this reduction which a semi-bankrupt nation like Germany cannot suffer. A system of socialisation in which the individual would work less and earn more would be more than disastrous for Germany. The Imperial Government intends, as is clear from the Bill relating to the management of the coal system, to tread the path of socialisation with all the prudence demanded. It does not advocate mechanical nationalisation, but the regulation of production by autonomous bodies.

Everything depends on how its intentions are carried out. Should it succeed in uniting all who are to take part in autonomous administration in earnest endeavour and in amalgamating opposing classes now torn asunder in the feeling of a common goal for their labour, the idea of joint management may well have fruitful results; otherwise it holds out no hope of salvation.

moulders' and labourers' work, he turned to his workers and asked them to allow themselves to be trained. He said: "We are out for shorter hours, higher wages, and more output; will you help us?" They said they would. His object was to train them so that needless movements could be eliminated, and so that they might adopt the best and worst expeditious methods. Each man in training had that instruction course, and as soon as he began to be trained his hours were reduced from 54 to 48 a week, and he received 25 per cent. higher wages than the ordinary day wage of the district as an inducement for him to go on with his training. When the men began to produce at the standard rate, then they were put on to a special system of payment to which he (the lecturer) would refer in his last lecture when dealing with the question of incentive. As soon as the men had reached the standard rate, they began to be put on this piece rate and bonus system. In the early days they did not fully appreciate it, and some of the older men were rather disinclined to give up the older methods; they were in a groove from which it was difficult to escape. To any such grumblers the managing-director said: "If you do not like it you can come to-morrow morning at six o'clock instead of eight, and go back to your old wages." He (the lecturer) believed that some of them would have done that if it had not been for the tact of the managing-director and his works manager. The result was as follows. At the outset the Ministry of Munitions had estimated that the foundry would turn out 3,000 of those articles a week. In fact they turned out 20,000. Part of that difference, of course, might have been due to an under-estimate on the part of the Ministry of Munitions; but as a better basis for comparison he (the lecturer) might mention that the managing-director had gone recently on a visit to a foundry which had actually more machinery than his firm had, and that while his firm was turning out 20,000 a week, the other foundry had difficulty in turning out 5,000; so that there was no doubt as to the enormous increase of output in his own foundry due to his methods. It was an extremely difficult matter, of course, to determine how much was due to the movement study, how much to shorter hours or higher wages acting as an incentive, how much to better food arising from higher wages—for there had been a striking improvement in the general appearance of the workers after the increase of pay—and how much to increased efficiency of the machinery and better organisation of the material. It is probable that in the actual moulding and casting about 90 per cent. of the increased output was due to improvement in the "human" factor, and of that more than 20 per cent. was due to a training in the best movements. In the machining, of course, the improvement was largely due to improved machinery.

He (the lecturer) would like to present a few figures to make the matter a little clearer. In the ten hours' day, worked under the old system, the foundry produced an average output of 48 of a given item. After the introduction of movement study the standard output, based on standard times, rose to 147 per day of 8¾ hours. That represented nearly 284 per cent. increase in hourly rate of output. But this standard output was regularly surpassed by all the adult workmen. The increase in earning in the case of one worker chosen at random was found to be, roughly, 200 per cent., and the reduction in working hours was about 11 per cent. When he (the lecturer) went to the foundry he interviewed, quite haphazard, fourteen of the men and women in the moulding and machine shops, and they were most strikingly content with the new system of things; they would not go back to the old state of things. There was no general evidence of increased fatigue; indeed many of them said the fatigue was less, and several of them preferred the new system because it involved less idling, or because under the old system they were called continually from one thing to another, whereas now they had a more methodical kind of work.

As another instance of the working of such methods elsewhere, an operation in moulding may be quoted which used to take 53 minutes, but which an expert reported could be done in 44 minutes. After practising, the men took 20 minutes on it, that is, an increase of 165 per cent. in the rate of output; and one of them averaged 16 minutes in a whole day's work. In another factory an operation taking 2·17 minutes was accomplished in 1·6 minutes. Further practice reduced it to half a minute. The scheduled time in which the work should be performed was, therefore, put—to make full allowances—at 30 per cent. over that half a minute, and in six months most of the girls had surpassed that by 30 or 40 per cent., so that they reached half a minute, which amounted to a 334 per cent. increase in rate of output, and the wages of the workers at the same time rising by 50 or 60 per cent.

In the Ferracute Machine Company in New Jersey, with practically the same equipment and the same number of employees, movement study reduced the time of performing 275 jobs by 38 per cent., and it reduced the total cost including overhead expenses, by 47 per cent. the average day rate paid to the workers being increased by 11 per cent., with a bonus increase of from 20 to 60 per cent. In the correspondence department of a printing office, where girls had to fold letters with enclosures, movement study increased the output by about 300 per cent. In cotton folding the movements were reduced from 20 or 30 to 10 or 12, and the result was that in place of 125 dozen pieces being folded, 400 dozen pieces were folded in the same time, without any increase of fatigue.

Everybody who had had to do with movement study laid stress, as might be imagined, on the importance of the initial training of new workers. If one could get hold of a man from the start, instead of allowing him to become fossilised in antiquated methods, or picking up his own methods (which was usually no method at all), one saved enormously. Of course, the principles of movement study were to eliminate needless movements, especially such as unnecessary stooping or standing, Bricklaying, for instance, was an extraordinary example of wasted effort in movement. It was in connection with bricklaying that Gilbreth did his first piece of work. When one considered that for centuries bricklayers have gone on stooping down and picking up bricks and when one thinks of the amount of work necessary in lowering and raising so much weight of trunk and head so many times a day—whereas one could save fatigue and increase output by placing the bricks and other things within convenient reach—it is really extraordinary how slowly improvements are being carried out. There must be a number of factories at the present day where it would not be difficult to devise comfortable seating accommodation with foot-rests and so on. That had been done very largely, in fact, especially in America, and that had effected a great saving of fatigue and increase of output. The elimination of needless movement was one principle of movement study. Another principle was to try to combine separate movements into a single movement, a continuous movement being always, of course, less fatiguing than two separate movements. Yet another principle was to combine as far as possible similar movements of the two hands at the same time. It required much more effort to raise one hand and then to raise the other, than to raise them both together; and a good deal of saving had been effected by that method of simultaneous symmetrical movements of the two hands. Another principle of movement study—he did not pretend that the list was exhaustive—was the attention to be paid to rhythm of movement. It was quite obvious how much less fatiguing it was to perform an act rhythmically than by a series of jerky movements; and, of course, every person had his own innate rhythm of movement, a rhythm peculiar to himself.

Having alluded briefly to the advantages of the system of trained movements, such as greater output, higher wages, and less fatigue, he would turn to the disadvantages. The great disadvantage which had been urged against movement study was one which would probably have occurred to his audience while he had been speaking, and that was the monotony of always reacting to one method. He did not think one could judge of that very well as an outsider, without inquiring from the workers themselves as to whether they found it monotonous. So far as his own experience went at the foundry he had mentioned, he had practically no evidence of workers objecting to the monotony. There were two people out of fourteen who spoke about it being monotonous, but when one came to cross-question them they were people who would have found the previous work monotonous. There were, of course, enormous differences in people, but he supposed the vast majority of factory hands, like the majority of domestic servants, preferred the even tenor of their way; they did not care to use their brains much; they just wanted to carry on day after day, doing the same things. So that a more or less monotonous occupation was actually welcomed by some people, just as there were others who could not exist without variety. There was another fact which should be borne in mind, and that was that a process might look monotonous to the outsider, and yet a person might be capable of taking great interest in it. It had been shown over and over again that it was very difficult to judge as to the monotony of an occupation. A great deal of one's own work, if someone else were to come and look at it, might appear frightfully monotonous, and yet it might be work in which it was possible to take a great interest, because one necessarily knew much more about it than an outsider. Where motion study had been practised, where a man had been shown the best method, if he was worth anything at all, he would take an interest in discovering a better one, and in a properly organised factory he would be rewarded—and adequately rewarded—for his discovery. So that where movement study had been practised, there was always an incentive to a good worker to discover some better method, and to report it to the manager. Then monotony might be guarded against by a proper system of promotion. That might not be possible in all industrial concerns, but it would be in a great many. If he (the lecturer) were a worker, for instance, he would wish to be trained part of his time for a higher post, and in return he would wish to be training someone else to take his place. Another way in which variation could occur would be to spend part of the time in teaching the employee not merely one little job, but other jobs at the same time, in order to allow flexibility of work, so that he could be transferred in cases of illness or of seasonal fluctuations in demand, from one job to another. It was obvious that there were many ways in which the danger of monotony could be avoided If one man was teaching another, for example, and the firm found that he was a good teacher, he could be made to undertake that work *par excellence.* But more important than any of those possible ways of safeguarding against monotony was to get the worker to take an intelligent interest in the factory as a whole, and so far very little had been done in this country in that respect. The worker should be educated in the general work of the factory, and should not be considered a mere piece of machinery. Movement study itself could not fail to bring the worker into closer contact with management, and, of course, it altered the whole system of apprenticeship. That so-called system was certain to fall after the lessons which we had learnt during the war. He wished to lay special stress on the education of the employee in the work of the factory and the results of his work, so that he might take a more intelligent interest in his own occupation.

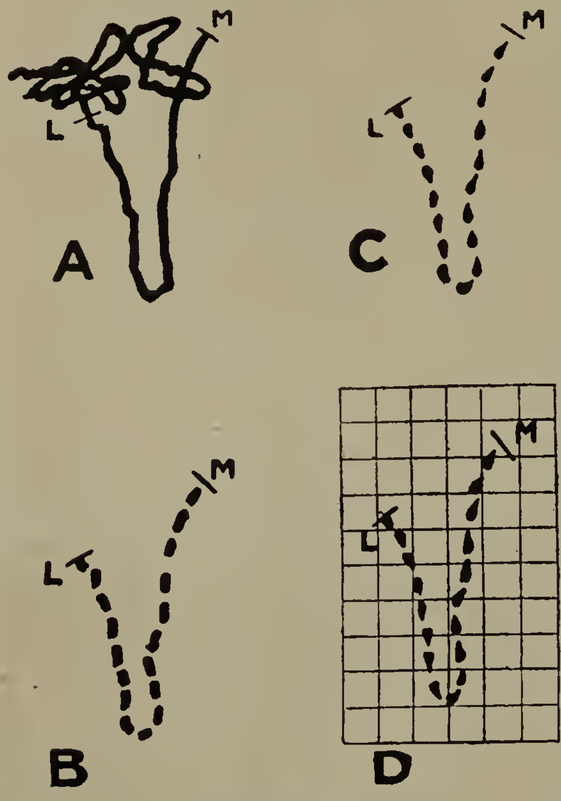

FIG 3.—DEVELOPMENT OF CHRONOCYCLEGRAPH.

With regard to the methods of scientific movement study, a good deal must be done in a special laboratory. It seemed to him (the lecturer) that two kinds of laboratories were wanted—one a central laboratory for the study of applied (industrial and commercial) psy-

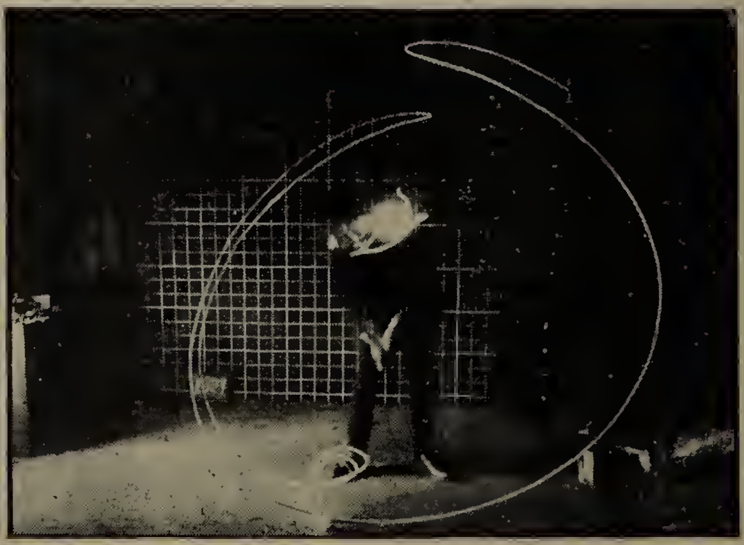

FIG 2.—THE BEGINNING OF MR. GILBRETH'S CHRONOCYCLEGRAPH.

chology, and the other, especially in the larger firms, a laboratory belonging to the firm. Both in the central laboratory and in the special laboratories attached to the concern, workers could only be trained with their full consent and co-operation. As regards this, there was a most terrible failure in the early stages of the movement in America. It was said of Taylor, for instance, who was the great leader of the movement, that he used to go into the factories with a book specially devised to contain a stop-watch inside it, so that the times of the workers' movements could be studied without their being aware of the fact. Nothing could be more disastrous to the whole subject than that. Taylor was, of course, a most capable and brilliant worker in industrial management, but such tactlessness as that had helped to put back the clock of progress of movement study a great many years. If it was thus introduced throughout this country the whole system would stink in the nostrils of the trade unions and the workmen generally.

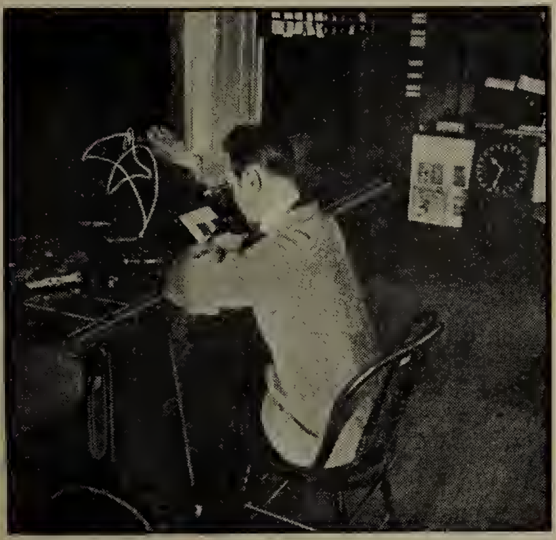

FIG. 4.

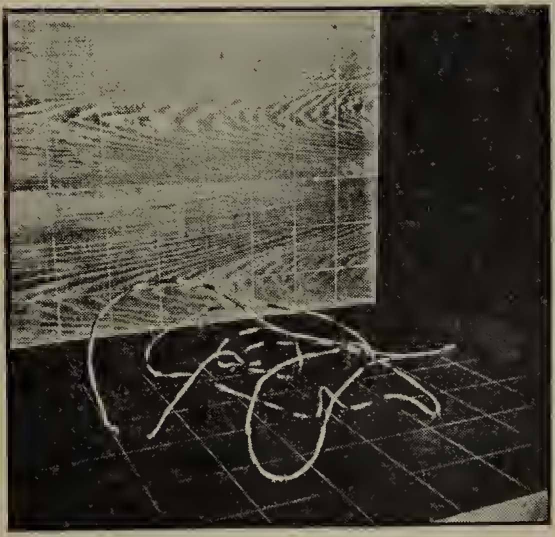

FIG 5.

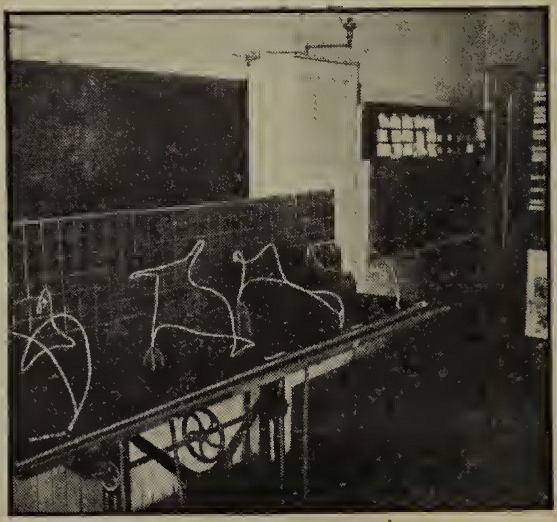

FIG. 6.

In regard to the actual apparatus to be used, of course, the simplest method was to proceed with a stop-watch; but Mr. Gilbreth had found that more refinement was often necessary, and with the development of the cinematograph he applied that instrument to movement study, so that an actual picture could be taken of the movements which were being timed. It was always difficult when one had merely a record of times to know precisely what the movements were to which the times referred. At first Mr. Gilbreth photographed a clock at the same time, so that the position of the clock hands in any one photograph indicated the time study as well as the movement study. But there were certain objections to the cinematograph, and for that reason Mr. Gilbreth devised what he called the "chronocyclegraph." In the first place, some obtruding part of the body was often apt to conceal in the cinemato-photograph an important phase of the movement. In the second place, when a photograph was taken it was limited to the angle from which the camera viewed the subject; whereas in the chronocyclegraph that was avoided. Lastly, the cinematograph was an awkward means of providing instruction, and also an awkward instrument for analysing the different movements. In the chronocyclegraph a wire model of the actual movements (Figs. 4–6) was ultimately made. That was a very much simpler method both for analysing the movements and for instructing the person, because he would see the whole of the movement before him; he could see any part at any moment he chose, instead of having to unravel the film, and, being just a wire model of the movement he could look at it from different directions, which was impossible in a film taken by means of a cinematograph camera.

Fig. 2 showed the beginning of Mr. Gilbreth's chronocyclegraph. It illustrated the movements of the American amateur champion golfer named Francis Ouimet, and formed a convenient introduction to Mr. Gilbreth's methods of elaboration of his chronocyclegraph. It might be described roughly as a method of photographing rapidly moving lamps. The end of Ouimet's club bore a small glow lamp, which showed the movement of his drive. It was a beautiful, graceful movement, characteristic of the practised artist.

Fig. 3 showed the gradual development of the chronocyclegraph. The movement from L to M corresponded in A to the picture of the American golfer; there was a continuous (here black) line of light. Mr. Gilbreth's next step was to introduce into the circuit a tuning-fork vibrating 50 or 100 times a second, so that instead of a single line of light he got a number of interruptions of light (as in B), owing to the current being interrupted, say, a hundred times per second. Then he went further, and introduced pointed dots of light (as in C), and that was done by breaking the current in such a way that the light glowed more faintly as it went off than when it began. The object of that was to have an indication of the direction in which the movement was going in the photograph, the pointed ends in the forward direction showing at once that the movement in the photograph was from L to M. Lastly, if one knew the distance between the squares in a wire screen (see D), photographed on the film beforehand, one had all the information wanted in movement study. But that was not all. Having got that photograph, which itself went a good way beyond the long continuous line shown in Fig. 3, A, and in Fig. 2, the photograph of the golfer, Mr. Gilbreth went further. Instead of a single photograph of the movement, Mr. Gilbreth took a double or stereoscopic one, so as to get the movement in relief, and, having got that stereoscopic effect, then a wire model could be built up.

Fig. 4 showed the building up of a wire model. The expert was shown looking down a stereoscope. He was just building up a wire model of the chronocyclegraph. He had a screen in front of him, which would tell him exactly the dimensions. Then, lastly, the wire model could be painted, as in Fig. 5.

Fig. 4 was a wire model of movement in working the drill press. Fig. 5 was a wire model obtained from the operation of folding handkerchiefs. The model was painted in black and white, and it was shaded from black to grey in order to show the direction of the movement, the grey being at the forward end.

Fig. 6 was of some interest, as showing the effect of practice on the movement illustrated in Fig. 4. He (the lecturer) was informed that the worker had previously been practised, but had not got back into his old stride. On the second attempt he got better; on the third he was better still; and, finally, he was his best, and that corresponded very closely to the original (of Fig. 4), which was the perfect model.

Differential Indexing.

THERE are several formulæ for the purpose of calculating the change wheels for differential indexing, which is a method of indexing for high numbers and primes, but all of them suffer from the disadvantage of being extremely cumbersome and intricate. The following method has the advantage of requiring much less calculation than any of the better-known formulæ :—

Let it be required to cut a gear wheel with a high prime number of teeth; select some number near to the number required, such that it can be obtained by simple indexing; then multiply number of teeth by fraction needed for one division of number selected; from result subtract number of turns of crank normally required to give one revolution of spindle; then difference over one equals ratio of gearing required.

For example, wanted, 107 teeth. Select division required for 100 teeth, say eight holes in the twenty circle. Fraction is $\frac{8}{20}$; multiply 107 by $\frac{8}{20}$, equals 42 8. Subtracting 40 from 42.8 gives 2.8; then $\frac{2.8}{1}$ =ratio of gearing. Multiplying out in usual way gives $\frac{2.8}{1}=\frac{56}{40}\times\frac{64}{32}$. When selected number of divisions exceeds number required, index plate must move in same direction as crank; when the contrary index plate must revolve in opposite direction; direction is, of course, determined by idlers.

Although the introduction of the differential system has to a great extent made compound indexing obsolete, there are still many occasions when the former method cannot be used, and there are also some machines which it cannot be used upon. On such a job, for instance, as a bevel gear, the differential system cannot be used because the spiral head is set at an angle and the gears cannot be put on. It must be clearly understood that a large prime number cannot be indexed by this method, for the reason that in indexing a prime by any method but the differential a circle must be used which is a multiple of the prime. The following method of calculation requires some slight knowledge of algebra, but it is a great advance on the usual methods; it is best explained by a concrete example. Supposing we wish to cut a bevel wheel having 51 teeth, 51 factors into 3 × 17, then $\frac{x}{3}\times\frac{y}{17}=\frac{40}{51}$; clearing fractions $17x\times 3y=40$. $3y=40-17x$; $y=\frac{40-17x}{3}$; by trial find integral value of x which will give an integral value of y; then raise denominators of fractions till they are equivalent to circles on index plates. When $x=2$, then $y=2$; then $\frac{2}{3}\times\frac{2}{17}=\frac{40}{51}$, that is $\frac{22}{33}\times\frac{2}{17}=\frac{40}{51}$,

That is a movement with the front index pin of 22 holes in the 33 circle; then two holes in the 17 circle with rear index pin gives a division of $\frac{40}{51}$. A further simplification is to set the front index pin for 17 teeth, that is, $2\frac{6}{17}$ turns; cut 17 teeth in blank by simple indexing, then make one compound movement as above; cut another 17 teeth by simple indexing, then repeat the process for the third 17 teeth, thus completing the job with only two compound movements. This method would be useful in the case of slotting an internal gear and other work where the head requires to be vertical or set at an angle, and other cases will, no doubt, suggest themselves to the reader. One particular instance occurred to the writer where it was required to cut a bevel wheel having 96 teeth on a Brown and Sharpe universal. As is well known, this number cannot be got by simple indexing on this particular machine. The calculation went thus:

$\frac{x}{6}\times\frac{y}{16}=\frac{40}{96}$; $16x\times 6y=40$;

$6y=40-16x$; $y=\frac{40-16x}{6}$; $\frac{1}{6}\times\frac{4}{16}=\frac{40}{96}$

$\frac{3}{18}\times\frac{5}{20}=\frac{40}{96}$; 3 holes in the 18 circle ×5 holes in the 20 circle

Industrial Accidents.

Economic Consequences of Permanent Disability—Accidents in California Disclosed by Official Statistics.

AN investigation has been made into the economic effects of permanent injuries suffered by industrial workers in California during 1916; it was carried out on similar lines to the Massachusetts inquiry for the three-year period ended June 30, 1916.

The study was based on schedules filled in by the Industrial Accident Commission of California, and included not only injuries resulting in the loss of a hand, arm, foot or leg, as in the case of Massachusetts, but also minor injuries. A comparison of the results of the two investigations shows striking similarities as regards length of total disability, capacity for re-employment, and relative severity of the various types of injuries.

The total number of cases investigated was 403; as regards injuries, the numbers were thus distributed:—Loss of hand or arm, 54; foot or leg, 34; eye, 45; thumb or one finger, 173; two or more fingers, 97. The average period of disability for these five classes of injury was 12.7, 13.4, 4.8, 2.4, and 3.8 months respectively. The average length of total disability for employees over 45 years of age was greater, in all classes of injury, than for those under that age.

As regards re-employment in the same occupation, it was found that, in the case of men who have lost an arm or leg, only about one-third re-enter the same occupation or return to the same employer, while of men who have suffered a minor injury, over one-third return to the same employer, and two-thirds follow the same occupation. Of the various types of injury the loss of an eye has the least effect upon the change of occupation of employer.

At the time of the inquiry only 9 per cent. of the injured men were unemployed.

In California it was found that 91 per cent. of the permanent foot and leg injuries occurred in non-manufacturing industries, and that 60 per cent. of these occurred in transportation and construction.

The effect of the injuries upon earning capacity was found to be difficult to estimate because of the constant increase in the wage level. Out of a total of 280 injured persons, 59 received less, 92 the same amount, and 131 more than they were receiving before their disablement.

Industrial Efficiency from the Psychological Standpoint.

By Charles S. Myers M.D., Sc.D., F.R.S.

Director of the Cambridge Psychological Laboratory.

(A Series of Four Lectures delivered at the Imperial College of Science and Technology.)

Lecture II.

(*See note at foot of page* 382.)

In his second lecture Dr. Myers distinguished between muscular fatigue arising from excessive activity, producing a clogging of the physiological mechanism with the products of that activity, and fatigue due to exhaustion of the living substance of the muscles, which was of extremely rare occurrence. He also distinguished between muscular and nervous fatigue, and pointed out that the greater proportion of occupational fatigue is of nervous origin. The central nervous system (the brain and the spinal cord) acted as a protection against muscular fatigue, and it was only in the extremely strenuous work of comparatively few occupations that there was a serious degree of muscular fatigue.

The ergograph enabled us to study the onset and course of fatigue in a single muscle of the living body. It yielded a record of the extent of successive contractions. In Kräpelin's form of the apparatus (Fig. 7) the hand was immovably fixed, by the clamps A and B, palm downwards, with the middle finger alone left free. That finger was attached by means of a metal box E, into which it fitted, to a wire passing over a pulley, a weight W being attached to the other end of the wire, and as the finger was voluntarily bent and extended to the rhythm of a metronome, a diagram of the extent of each flexion of the finger was recorded by a lever L, which was attached to the wire and brought to bear on a travelling smoked surface. He did not regard this instrument as an indication of organic (muscular) fatigue. It was rather a record of the capacity to work under special conditions. For, supposing that the weight to which the finger had become fatigued was 5 kgs., a new ergogram (Fig. 8) could be at once obtained by reducing the weight to 4 kgs.

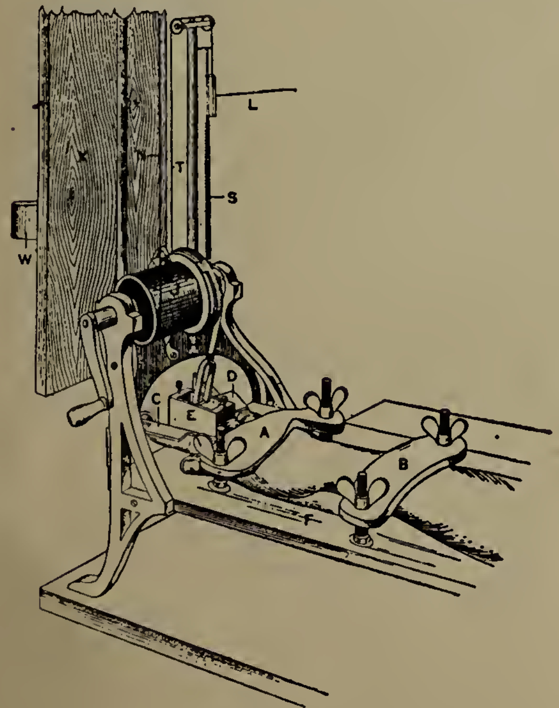

FIG. 7.

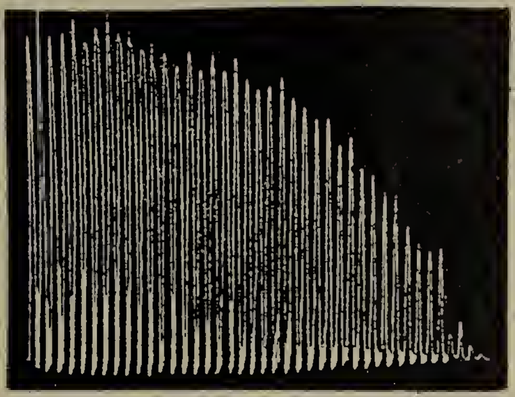

FIG. 8.

The fatigue occurring in ergographic work was therefore not true organic (muscular) fatigue. It was a functional (nervous) fatigue, due *not* to *excessive* but to *monotonous* work, and relieved by changing the conditions of work. The fatigue was due to nervous impulses ascending to the central nervous system from the muscle, and there preventing or inhibiting further muscular activity. Nor did muscular work serve as a test of general or felt fatigue. When a person was actually fatigued or felt fatigue, he might temporarily do far better muscular work than when he was not. Conversely, the fact that a person felt fresh did not ensure that he would be able to do the best work. Alcohol, for instance, and even certain states of fatigue produced a feeling of ability to work, but the work might fall very short in quality if not in quantity of the work done in other conditions. Therefore, feelings of fatigue or freshness were no test of the work that could be performed.

Any mental work which created monotony eventually caused distraction, conflict of motives, and worry, ending (if continued) in neurasthenia or nervous breakdown. It was extremely rare to get neurasthenia from mere muscular activity. There had been cases in the war where men had been absolutely worn out by long marching, but few cases of neurasthenia had resulted from sheer muscular exhaustion. By far the greater proportion of cases of nervous breakdown were due to the worry and anxiety arising from the effort to overcome the conflict of opposing motives, and monotony of occupation was one of the possible causes of such conflict. There was a great fallacy in supposing that fatigue did not occur to persons who worked at light work for long hours. They were subject to the functional fatigue arising from monotony. That weariness might at an early stage be circumvented by change of employment, but eventually only rest and recreation would dissipate it.

For these reasons, the ergograph gave little promise of affording an index of occupational fatigue. The best means so far known of estimating such fatigue was by a study of hourly output during the day (*cf.* Fig. 9). A less reliable method was by observing the machine power hourly used. Yet another

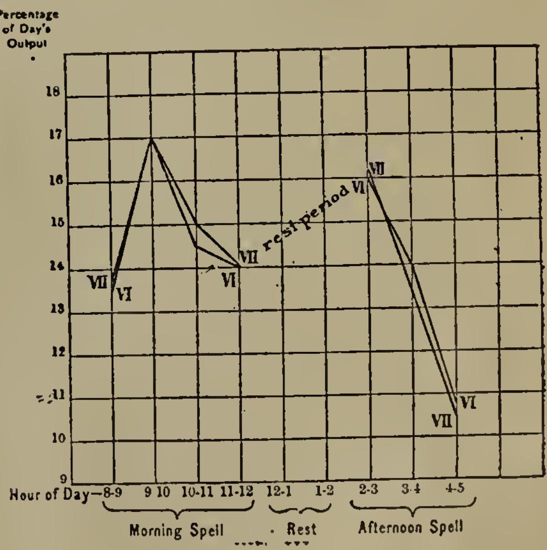

FIG. 9.

was by a study of the amount of spoiled work, the assumption being that as fatigue increased there must occur more and more spoiled work. Again, the number of accidents arising through carelessness afforded some index of the degree of fatigue of the workers (see Figs. 10, 11). In the London Docks, for instance, more than 25 per cent. of the accidents occurred between 11 a.m. and noon, and between 3 p.m. and 4½ p.m. Towards the end of the morning they were more frequent than at the beginning, and towards the close of the afternoon they again became far more frequent, which was, as would be expected, the course which fatigue would follow. Lastly, the amount of lost time might serve as an indicator in fatigue estimations. But there must be taken into account the reduced number of the machines working towards the end of the day, and also the frequent presence of a "spurt" towards the end of the day, which to a varying extent marked the underlying fatigue. These were complicating factors which inevitably entered into the problem.

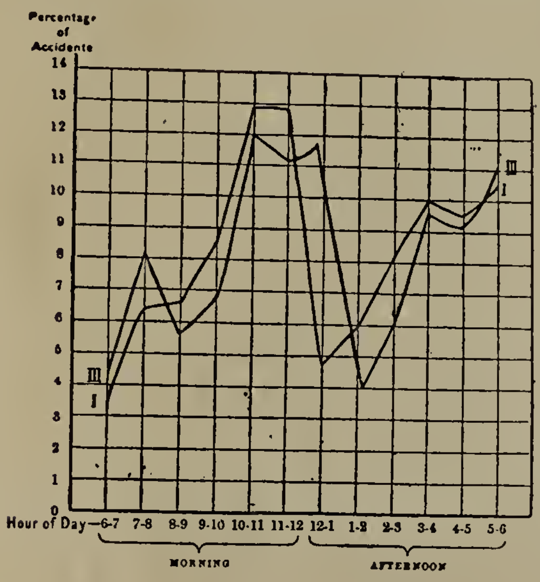

FIG. 10.

In America, Lovett and Martin had devised a test in the form of a dynamometer, which was in effect a spring balance, and the average strength of pull obtained from a number of muscles in different parts of the body was used as the basis for the estimation of fatigue. This spring balance was pulled against by the forearm, wrist, leg, etc., and the person used all his strength to resist the increasing traction of the spring worked by the examiner. It was very desirable that the value of these tests should be confirmed in this country. There was always a danger of inaccurate results when such a test as this was interpolated at various hours in a man's daily work. There was the possibility of conscious limitation, which perhaps might not be appreciable; but there was the certainty of a change of interest in passing from this day's work to the test, and the results of such change of interest might be favourable or unfavourable to the test.

If a test must be interpolated, it should be such as not to be under the subject's control. Other tests which had been suggested with this object referred to changes in the blood circulation and in the gaseous exchange in respiration. But these could not be expected to indicate the most important source of fatigue, that of the central nervous fatigue. Then there were mental tests, but the dangers he had mentioned in regard to the interpolation of tests for muscular fatigue were still more applicable to mental tests, such, for instance, as speed of reaction, memory tests, keenness of vision and hearing. Therefore, if mental tests were adopted it was better that they should constitute a continuous test, say for half an hour or an hour. One mental test of this kind consisted in the addition of long columns of single figures, each successive pair of figures being added and the result written down, with a view of seeing how much work of this kind could be got through minute by minute. As the subject got mentally fatigued so the curve of output fell off. Another similar method was proof correcting, the test consisting in crossing out as many e's in a minute, the number in each minute being recorded. There was also McDougall's dotting test, in which small circles printed on a long strip of paper had to be dotted at their centre, as they passed before the view of the worker.

In these tests, of course, the factor of practice entered, and where the practice was considerable the mental work curve actually went up instead of down. Considerable practice was therefore necessary, before they could be successfully employed. In all these tests, there was noticeable an "initial spurt" when the subject started fresh and a similar "end spurt" occurred towards the close of the day or the morning. In the same way in the industrial curves of output, as the holidays approached, there was a well-marked spurt. In a munition factory the work of women engaged on turning fuse bodies was found to increase by from 6 to 10 per cent. just before Christmas, but there was a fall of 16 per cent. immediately after the holidays, but after a while the output reached 12 per cent. above the pre-Christmas maximum.

This fall after a holiday was partly due to a further factor in the work curve known as "incitement." It occurred if the worker was taken away from work even for two or three minutes. When he went back he had "grown cold," so to speak, and, like a machine, wanted "warming up" again before he got going as before. Allied with that was the factor of "settlement," the ability to settle down in spite of initially distracting influences. When a worker was taken away from his work for a while, he lost incitement and also settlement, as well as practice, but he gained as regards fatigue, and he also gained because of the initial "spurt" with which a return to work is often accompanied.

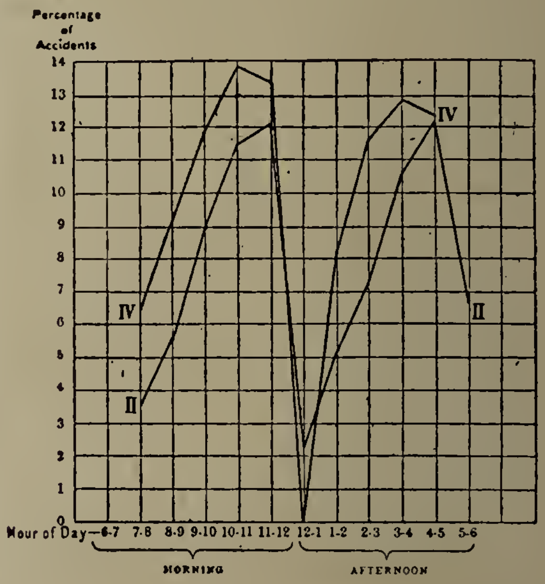

FIG. 11.

A good deal of work had been done in the psychological laboratory in determining what was the most favourable rest pause. It was clear that when all these various opposing factors influencing the work curve were taken into account, there must be a rest pause of a certain length after a certain period of work, which would be more favourable to subsequent work than a pause of greater or shorter length. This work in the laboratory was being continued and was capable of almost endless extension in regard to industrial matters.

It was, of course, to be expected that the curve of industrial output must vary considerably with the kind of work done. When the work was extremely monotonous or extremely strenuous, there must occur a very striking, perhaps steady, fall in the work curve. When it was varied, rhythmical, interesting or not too strenuous, little falling off might be expected towards the end of the day. Work demanding more attention and dexterity would be expected to yield a work curve intermediate between these extremes. Clearly we were largely at the beginning of this work in industrial psychology and physiology.

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Industrial Efficiency from the Psychological Standpoint.

By CHARLES S. MYERS M.D., SC.D., F.R.S.

Director of the Cambridge Psychological Laboratory.

(A Series of Four Lectures delivered at the Imperial College of Science and Technology.)

Lecture III.

IN his third lecture, Dr. Myers spoke of the factors to be taken into account in industrial fatigue. One of the most obvious was the load a man could carry. Fortunately, in these days of increasing application of machinery, that factor was becoming of less and less importance, but he would like to refer to some striking investigations made some years ago by Taylor in America, on men who were engaged in loading railway trucks with pig iron. Each piece or "pig" weighed 92 lb., and the men had been previously engaged on the work without any selection. Taylor found that for pigs of this weight, the men should not be under load for more than 43 per cent. of the day; that is to say, in a 9-hour day the time under load should be 4⅓ hours. He set the men to work for seven minutes, and after each such period he gave them a rest of 10 minutes. At the same time he selected his men, having noted that some of them (12½ per cent.) were far better suited to the work than others. On this basis of work and rest and selection, he found that the men, instead of lifting, as they had done before, 12½ tons per day lifted 47½ tons per day (equivalent to about a 300 per cent. increase in output), and that there was certainly no more fatigue than by the old method. In addition, wages were higher by 60 per cent., and there was a 66 per cent. reduction in the costs.

Fatigue was induced by needless standing, and should be avoided by arranging the work bench at a proper height, so that the employee could sit wherever possible. Unnecessary stooping was another point to be watched for. There was the now classical instance of the bricklayer who had been content for centuries to lower the weight of his head and trunk in order to stoop to pick up bricks and mortar, when this useless labour could be readily overcome by arranging the bricks and mortar at a suitable height.

Illumination must also be taken into account, particularly the avoidance of glare from polished surfaces. The opposite defect was to have too little light. In one factory the lighting was increased from 4,000 to 12,000 foot-candles, and at the end of a month the output was increased by from 8 to 27 per cent., the only change being the better lighting. Deficient lighting was the cause of miners' nystagmus, which consisted in an involuntary tremor of the eyes. It had conclusively been shown that this was due to the very poor light of the miner's lamp, which often did not exceed ¼-candle power.

Noise was a further factor. There was a case on record in which an increase of 25 per cent. in output was obtained by moving certain employees to comparative quiet away from the noise of a yard. Vibration of machinery also well repaid investigation in regard to its effect on the output of workers within its influence. Ventilation, humidity, and temperature were important matters to take into account. Experiments had been made on animals subjected to different degrees of temperature and humidity to watch the degree of exhaustion produced, under the following conditions:—

Temperature	Humidity
69 deg. F.	52 per cent.
75 ,,	70 ,, ,,
91 ,,	90 ,, ,,

Assuming that at 69 deg. temperature, and 52 per cent. humidity, the work done was 100, as the temperature and humidity were increased as above, the amount of work done was found to fall to 85 and 76 respectively.

In some recent work in regard to the tinplate industry, it had been considered that at least 12 per cent. more output would be obtainable by efficient ventilation.

Another psychological factor which tended to increase output was security against danger. In dangerous trades, the workers showed a tendency to neurasthenia, and that was especially marked among coal miners. In cases of nervous breakdown during the war, a disproportionately large percentage was found to occur among miners. Other obvious factors conducive to an increased output and the reduction of fatigue, were proper food, cleanliness, canteen and club comforts, library facilities and other similar matters now generally comprised in welfare work.

A great deal more investigation was required as regards the effect of continuous night work. During the war it was found that the best effects of nightwork in certain occupations were obtained if the workers did not work for more than a fortnight, and were then turned over to day work. There could be no doubt that night work could never be really efficiently carried on unless proper dormitories were provided for the night hands, so that they would be sure of getting a rest in the day time. It was possible to imagine without much difficulty the kind of sleep that an ordinary work hand must get when he or she went home after night work, amid the social conditions under which many of the workers lived. Again, nothing was shown more clearly during the war than the advisability of avoiding before-breakfast work and overtime. Even in peace time, before-breakfast work had been shown to be practically worthless; and as regards overtime, the worker simply "saved himself" during the day when he knew that he had to work late. This saving was largely involuntary, due to the physiological organism setting up an unconscious defence against the prospect of excessive hours.

Passing to the effect of rest periods, the lecturer said that those who had been in a factory where a rest period of ten minutes had been enforced have described how the whole room seemed to take a deep breath. Laughter and talk broke out. The relief was astonishing. In America some figures had been taken out as to the effect of introducing a ten minutes' rest in each spell of a ten-hour day. As a result, there was a 3 per cent. increase in output during the first period under observation, and this increase continued in the second and third periods, until it reached 17 and 26 per cent. respectively. In a bleaching factory a 20 minutes' rest was introduced after each spell of 80 minutes' work, and a 60 per cent. increase in output was recorded, accompanied by a 50 per cent. increase in wages. In one of our own munitions factories, 15 minutes' rest was introduced after every 45 minutes' work, and a very definite increase in output was recorded, although he had not the exact figure. The employees in this factory were paid by piece rate, and they grumbled at first at the enforced rest periods, because they thought they would lose money by it, but there was a very distinct increase in their output and consequently in their earnings.

Rest Periods.

Another interesting case on record was that of two rival groups of soldiers which were engaged in seeing who could make the greater number of yards of trench at the front. The officer of one group divided his men into three sections, so that he was able to give each section five minutes' rest after every ten minutes' work. Thus they were working continually in relays. The other officer worked his men in the ordinary way and employed no system at all. The first group won easily, solely through the systematic rests which were introduced. This demonstrated how necessary it was for further investigation into the question of introducing rests. By giving a rest period they were avoiding fatigue, and the work lost during the rest period was more than made up by the increased output which the workpeople produced after each rest. At the same time, there must be something lost in the process of "warming up" after each rest period, and it was only by careful investigation of figures of output before and after, and by varying the time of introducing the rest period and its length, that reliable information as to the best methods could be obtained.

With regard to the factor of reduced hours, some striking results had been obtained in our own munitions factories. In the case of men engaged in the heavy work of sizing fuses, the hours were reduced from 58·2 hours to 51.2 hours per week, a reduction of about 12 per cent., with the result that the hourly output was increased by 39 per cent. But hourly output was not of so much interest to the employer as the total output, and in this case the total output was increased by 22 per cent. In the case of women engaged in the moderately heavy work of turning fuse bodies, the hours were reduced from 66·2 to 54·8 per week, a reduction of about 17 per cent., and the result was a 34 per cent. increase in hourly output and an 11 per cent. increase in total output.

A striking instance had been recorded by Stanley Kent, who investigated some yarn winders in a surgical dressing factory. This work required a great deal of attention in watching for broken threads. The daily hours of work were from 6 to 8, from 8.30 to 12.30, and from 1.30 to 5.30, a total of ten hours per day, with overtime worked from 6 to 8 p.m. That made in all a 12-hour day. There was one woman among the employees who said that she could produce a greater output than the rest by not working before breakfast and not working overtime. She was tested against three first-class hands for a month, she working for 8 hours a day, and the others working for 12 hours per day during the first fortnight, and 10 hours per day during the second fortnight. During this month the woman took a whole day's holiday, and two half-days, and yet at its close she beat the average of the other three. Her output was 8 per cent. greater than the others, and the latter showed a 5 per cent. greater output when working 10 than when working 12 hours a day.

During the Coal Commission enquiry it was declared that, although the Durham miners worked 7 hours a day from bank to bank, or an hour less than the others, yet their output was fully equal to that in other districts.

The lecturer then turned to the study of selection. There were, he said, some people such as artists, poets, musicians, inventors, who inevitably adopted their profession because of their genius. Most people, however, were only gifted at most with what was known as talent, and to a certain extent this talent gave a choice of occupation. Many people, of course, chose occupations for which they were best fitted. Others, subject perhaps to the advice of friends and relatives, would often choose the wrong occupation. Some would act on tradition and follow the occupation of their father and grandfather. Others would choose their employment, actuated by expected influence. With these various and often detrimental factors at work, it was hardly surprising what an enormous waste of effort and expense arose through people choosing the wrong occupation. Nothing had struck him more during the war in enquiring of men what they had done in civil life than to find how many had passed from occupation to occupation until they got something which suited them. This wasted effort seriously affected the employers also. Some statistics had been prepared relating to a munitions factory in the United States, where it was shown that during six months, of 10,000 employees who left the works, only 10 per cent. left for reasons known to the employers. That was during the war, but as showing that this wastage was not confined to the war period the lecturer quoted a factory in this country, which was also a munitions factory before the war, in which it was found, before the war, that of 1,000 women entrants into the firm, 658 left after six months. During the war the figure only increased to 671.

Vocational Guidance.

For each individual there was probably one occupation which was more suitable than any other, and in every occupation some succeeded better than others. What could be done to remedy the state of affairs to which he had referred ? Obviously something could be done in the way of a vocational guidance department for girls and lads on leaving school. A great deal could be done by an interview, aided by a knowledge of the school records and of the special requirements and openings in different occupations. At any rate, such a procedure would help in coming to a broad decision as to whether the boy or girl would be best fitted for mental work or manual employment, for indoor work or outdoor work.

Discussing the advantages of selection of workers for particular work, Dr. Myers referred to a bicycle ball-bearing factory where the girls, holding the balls on the back of their hand, in one of the spaces between two fingers, had to observe whether there were any defective balls and to remove them by means of a magnet. These girls were tested experimentally as regards their speed of reaction to light, and those were selected who showed the quickest reactions. The girls who proved least suitable were transferred to another department. The result of this selection was that

35 girls produced the same output as that of the previous 120 girls. Their hours could be reduced from 10½ per day to 8½ per day; they were given two days holiday per month; their wages were increased by 100 per cent.; the accuracy of the work was raised by 66 per cent., and there was a large decrease in cost. Another example of the value of selection was in connection with tram drivers. Here the test aimed at proving the man's power of seeing what a man who was crossing the road was likely to do, or the direction a cart was likely to take, and how quickly the driver was able to react appropriately to conditions of that kind. The result showed a remarkably close relation between efficiency at the tests and the actual records of accidents against the men. The men who showed up best in the tests had the fewest number of accidents recorded against them, It was obvious, therefore, that a ten minutes' test of that kind would save many an accident.

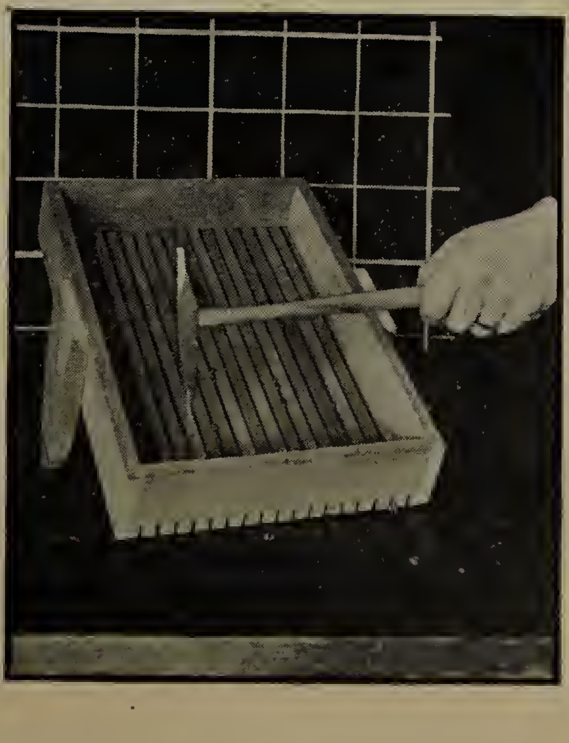
During the war, candidates for aeroplane works were tested very severely before they were finally accepted. Their vision was examined as regards stereoscopy, and also in regard to being able to adapt itself quickly to darkness. The subject was also tested in his ability to recover balance by means of lever-movements, the seat being tilted. There were also tests as to how faint a sound could be heard, and how accurately it could be localised, which was important in listening for hostile aircraft or submarines. The result of these and many other psychological tests was to effect an enormous improvement in the class of men selected for special training.

With regard to military intelligence during the war, certain candidates were systematically examined and trained in the accuracy and speed of observing combinations of colour, the position and attitude of men in groups, keeping direction, finding the way, and so on. This class of work was carried out in great detail in the United States, where a group of psychological and industrial specialists were employed in applying tests by which the educational level, intellectual ability and previous special experience of every recruit entering the U.S. army was recorded, and by this means it was found possible to save several months of camp life in the selection of non-commissioned officers, and to earmark men for special army work.

All this, the lecturer thought, led to the conclusion that psychological tests are needed, first of all in choosing a vocation at the outset, and secondly, in drafting the employee who was already in one part of a factory to a part more suitable. The old way had gone, he hoped, in which a number of men seeking a job stood in line and saw the representative of the employer through a window, each hearing everything that was said to those who were interviewed before him. Already we had begun to apply psychological tests for railway men for colour vision, and it was obvious that for sailors, systematic tests of hearing were required. A great deal of preliminary work was still necessary in determining the qualities desirable for employees in the various branches of commercial industry. It was quite clear that what was wanted were central laboratories of applied psychology in order to devise tests and collect standards, because it was essential to arrive at the standards or averages, in order to see to what extent subject fell short or otherwise of them. In such laboratories it would be necessary to train testers, to advise educationists, employers, and, he hoped, trades unions. That was only a step to having psychological laboratories in the larger factories, and advisory bureaux connected with labour exchanges where employees and lads and girls leaving school could be examined and tested for their fitness for different occupations. He was convinced we should come to this state of affairs sooner or later.

A Tool for the Disabled.

THE soldiers of industry as well as of war claim the assistance and sympathy of everybody, and we illustrate herewith a simple device originated by Major Frank B. Gilbreth, of Providence, R.I., which enables a one-armed man to use a hammer and nails. In such a simple operation, the only use of the left hand is to pick up and hold the nail, until it is knocked into the timber, and how often is the thumb hit and injured by the unexpert in the process? Most of us have undergone this painful experience.



The novelty of this device is a wooden box, the bottom of which consists of slats, about ⅛ of an inch apart, the whole being mounted on rockers A handful of nails being placed in the box, it is rocked until the shanks of the nails fall between the slats, leaving the heads uppermost. The worker is provided with a hammer, the head of which is magnetised, and picks out one nail at a time. A slight tap is enough to embed the point in the wood, and it is then driven home. Workers provided with the apparatus have been employed in box making, etc., and after a short experience have proved their ability to turn out the finished article—well made—and in equal quantities to those made by two-armed workers.

Boiler Economies.

IN place of ordinary cast-iron links in chain grate stokers, which were found to have a very short life—some 3,000 to 4,000 hours only—on account of the inferior dry coal available during the war, experiments were made in Germany with links of rolled steel. These are said to have proved superior; they did not break or expand sufficiently to obstruct the air-spaces between the links, and upon examination after 7,800 working hours were found in a perfectly satisfactory condition. It was also found possible to use driving-links ¾-in. thick only, which permitted a more uniform fire and decreased the weight of the grate. The fire bridge and dumping bars at the end of the chain grate were found to deteriorate quickly, and recourse was had to water-cooled metal fire bridges, together with dumping bars suspended as pendulums and provided with air spaces and cooling ribs.

The air entering at this point is heated by passing over the ashes, and assists combustion without damaging the pendulum bars. It is possible to utilise the grate as far as the pendulum bars, which is not the case with ordinary dumping bars; consequently less skill is required by the attendants, and a fuller use is made of the grate surface, resulting in greater efficiency as evidenced by a higher percentage of carbon dioxide in the flue gases.

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Industrial Efficiency from the Psychological Standpoint.

By Charles S. Myers, M.D., Sc.D., F.R.S.,

Director of the Cambridge Psychological Laboratory.

(A Series of Four Lectures delivered at the Imperial College of Science and Technology.)

Lecture IV.

In his final lecture Dr. Myers dealt first with restriction of output. Output might be restricted by the employer or by the employee, and either of them might restrict it deliberately or more or less unconsciously.

Deliberate restriction of output by the employer might occur through at least three causes, viz., dearth of raw material, the fear of flooding the market and the need of co-ordinating the requirements of different departments of the factory. Obviously if more were produced in one department than could be used in the others, there would be a tendency for the employer to restrict the output of that department. More or less unconscious restriction of output by the employer might occur through want of organisation in the factory, bad planning of machinery, deficient training of the employees in "movement study," ill-considered arrangement of the working hours, inadequate rest pauses, and defective selection of employees for the task for which they were best fitted.

Restriction of Output.

In regard to restriction of output by the employee, an important cause was the fear that with increased output the rate would be cut when payment was made by piece rate. That had not infrequently happened when men began to earn more than the employer had thought possible when setting the rate. The employer might object to the employee earning too much, and consequently he cut the piece rate. There was a case on record of a girl paid by piece rate, who was shown a more efficient method of working by which she could earn far more money. But later she was found to have returned to her old method, and the reason she gave was that the employer would cut the rate if a girl earned more than a certain sum per week. A worse example—indeed of almost unparalleled industrial barbarity—was the case recorded, also in the United States, where a bonus of 25 per cent. was paid if a job was completed in a certain time. A bonus was also given by the employer to the time-setter, this bonus being based on the number of failures of employees to earn the bonus, so that the more employees who failed to earn the bonus the larger the bonus to the time-setter. Consequently the time-setter put a time on the job so that very few employees could earn the bonus. A further refinement in cruelty consisted in the fact that the foreman was given a bonus on the number of men who earned the 25 per cent. bonus, so that the workpeople, while given a task by the time-setter so severe that few could do it, were at the same time being driven by the foreman to do their very best at this almost impossible task. Although such extreme cases had not occurred in this country, yet there were many instances in which the rate had been cut here, and it was undoubtedly an important cause of the deliberate restriction of output by the employee.

Another cause was the fear of disloyalty to less capable fellow-workers. These were the two main causes of the conscious restriction of output by employees. He would refer later to the attitude of trade unions to wage systems, but he wished to point out that the restriction of output by workers had been shown to occur in what Americans called "open shops," *i.e.*, where there was no trade unionism, as well as in shops where the men were members of a trade union. Therefore, it must not be thought that restriction of output was limited to trade unionists.

More or less unconscious restriction of output by the workers was due to general slackness, tradition (it had always been their habit to turn out so much) and the establishment of a general factory routine which would be upset if there were an increase in production in any one department.

A few examples were given from munition factories. Night after night the output of 16 women drilling fuses was 3,800 precisely. If the machines stopped for any reason, they evidently put on a spurt afterwards, because the output remained the same over the period of examination; indeed, it was found that this spurt was capable of from 75 to 90 per cent. temporary increase in rate of production.

Another example was that of six women occupied in gauging fuses. Five of these women regularly, day after day, gauged 1,315 fuses exactly, A man, who was observed for 45 days in finishing fuses, got through, with the exception of one day, exactly 1,000 fuses per day.

A striking instance which occurred in this country was the following:—In the older shops of a certain factory 5,000 of a certain article were produced weekly. The firm decided to open a new shop, and the mechanical conditions were practically the same as in the old shops, but inexperienced hands were employed who were untrammelled by tradition and knew nothing about the work. At the end of six months' practice this new shop produced 13,000 of the articles per week, whereas each older shop, with its restriction of output, only produced 5,000.

Unconscious Restriction.

Another case on record was that of six units of machinery, each of which produced 2,500 articles per week, the total output being therefore 15,000. It was decided to remove some of the machinery, unit by unit, and at the same time a bonus on output was given to the workmen on the remaining units. When the first unit was removed, the output on the remaining five was still 15,000 per week; when the second, third and fourth units of machinery were removed, the output nevertheless kept at 15,000 per week—an increase of 200 per cent.

As possible evidence of the increasing restriction of output in this country, the following table and figures were given:—

Value of Output per Worker per Annum.

	U.K.	U.S.A.	Australia.
1886	£316	£400	£333
1906	£275	£596	£406
1902	£244	£600	£542

It had been calculated that in the United States the average wage was from three to four times that in the United Kingdom and that the average hours of work were from 20 to 40 per cent. less.

Another instance of lessening output in Great Britain was the number of bricks laid in plain walling per worker per day. In 1885 the number was from 1,200 to 1,500 per day, and by 1912 this had dropped to from 500 to 600 per day.

One method of detecting restriction of output was to take the average of a number of workers on the same job over a determined period and to observe how the individual worker's output fell short of or exceeded the average. Excessive uniformity among different workers was suggestive of restriction. The forms of the individual work curves so constructed were also instructive. If they went up considerably towards the end of the day, there was reason to suspect that there had been restriction earlier in the day (leaving out of account, of course, what he had already referred to as the end spurt). At the same time, it was difficult to lay down any definite rules as to the effects of restriction on the work curve of the individual. While some workers might prefer to restrict earlier in the day and to make up for it at the latter part of the day, others might push hard at the beginning of the day and slacken towards the end. But any such departures from the normal would easily show themelves in a study of the individual curves of output

Where several workers contributed jointly to a given job, there was apt to be uniformity of output, and, of course, where a number of men were needlessly engaged upon a job there was bound to be restriction of output. A case of this kind was on record where three or four men, engaged in loading coal at one centre, were paid six cents per ton, while men engaged at another centre on similar work were only paid four cents per ton. Seven men left the latter to go to the former centre because of the higher rate there, but they soon came back again, saying that they could not earn so much money at six cents per ton on account of the slackness prevailing through the larger number of men employed on one truck.

Although, no doubt, there would be a great deal of opposition by the upholders of the present apprenticeship system, he thought there was no doubt it would have to undergo a thorough change. Far too much importance had been attached in previous years to the importance of a long apprenticeship, accompanied by unsystematic instruction. During the war, in industries where it had been supposed that a considerable time was necessary to train a person to be skilled in any special line, it had been shown that after quite a short time excellent work could be turned out, if only proper methods of training were used. If an impartial inquiry were conducted into the apprenticeship system as it existed before the war, in the light of the experience of the war, he would imagine that a large number of important recommendations could be made.

Output could be abnormally increased by making more use of machinery, and it was calculated that the United States used from two to three times as much power per worker as we did in this country. For instance 50 per cent. of the coal mined in America was cut by machinery to eight per cent. in Great Britain. At the same time, he did not mean to suggest that these figures were strictly comparable. Coal cutting in America and Great Britain had been run on very different lines; it was difficult therefore to compare the conditions, but, on the other hand, it was difficult to resist the conclusion that a great deal more could be done towards increasing the output by the greater use of machinery in this country.

Machinery and Output.

In the production of yarn, for example, it had been calculated that 25 men and boys now produced by machinery the total amount of yarn which was produced by hand 200 years ago, the working hours being from six to seven less per day. Unfortunately many of the workpeople in England held the view that the introduction of machinery must necessarily involve reduced employment, and it was overlooked how the increased use of motor cars, bicycles, gramophones and many other things, simply because, owing to improved machinery, they were now made in numbers, had led to increased employment. The reduced cost at which such articles could be obtained was in itself an equivalent to increased wages, and their spread through the community resulted in a higher standard of living.

The introduction of machinery into the cotton industry had produced remarkable results in increased employment. Before Crompton and Arkwright made their inventions, there were only 8,000 operatives in the British cotton industry. Twenty-seven years later there were 300,000; eighty years later there were 800,000; and if those engaged in machine manufacture in connection with the industry were included, there were now 2,500,000 workers engaged in it.

Dr. Myers next came to the subject of the methods of pay, one upon which, he said, he was very diffident of saying much, but no lectures on the psychological aspect of industrial efficiency would be complete without some reference to this matter.

Profit-sharing had only been tried in certain special industries and in some small towns, and it was urged that the advantages of profit-sharing were only to be obtained under unusual conditions. Returns showed that the average life of profit-sharing schemes was not very long—about five years. An objection to it was that it involved no share in the losses. Another objection was that the bad worker obtained his share of the profits as well as the good worker. Yet another was the fact that the profits were only distributed every six or twelve months; the reward was therefore remote. It was interesting to note the amount which would be taken by the individual workman if profits upon capital were distributed amongst labour. Taking capital and population on a pre-war basis, and dividing all interest and profit on capital among every inhabitant in the United Kingdom, it had been calculated that each individual would get 11d. per day; or, if the excess profits during the war were taken and divided among the employees, it had been calculated that each would get four shillings per week advance in wages, whereas the actual average advance had been considerably above a pound a week. If the net annual profits of the cotton industry for 1907, viz., £7 per operator, had been added to the wage of the workers, each would have received an increase of 15 per cent.; *i.e.*, a four-shilling wage would be increased to 4s. 7d. If, however, the output could be doubled and the value and cost were assumed to remain the same, then the net annual profit per operator would be £86 instead of £7, so that there was an enormous gain to labour in increasing output.

As to methods of payment and the piece-rate system, there was the straight piece system and the differential piece rate. The objection of rate-cutting to the straight-piece rate he had already referred to. The differential rate system was proposed by Taylor, and was based on time-study determination; two piece-rates dependent on rates of output were set—one lower than current wages and the other considerably higher. There were two great objections to it; one was that there was no fixed minimum day wage, and the other was that the system permitted of a sudden jump which might be unfair to a workman who was kept on the lower rate when his production of another piece would have taken him into the higher rate. Gantt introduced a bonus, which was added to the day rate in proportion to the time saved. Thus if a man succeeded in doing in forty minutes a task scheduled at one hour, then he was given a bonus of 33.3 per cent., that being in proportion to the time saved. Supposing the day rate was 30d. per hour, and the job was finished in forty minutes, the rate was raised by 10d., making 40d. per hour, but as the man had only worked 40 minutes, he would get two-thirds of 40d., equal to 26·6d. for 40 minutes' work.

Another system put forward by Emerson was called the premium system. A certain standard was set, and if the man reached it he was said to have 100 per cent. efficiency. A small bonus was paid as soon as 67 per cent. efficiency was reached; it was increased as he approached 100 per cent. or exceeded it.

There were numbers of other systems; for instance, Halsey's premium system. If the man had a day rate of 30d. per hour, and he did a task in 40 minutes for which the standard was one hour, he would get $(20 \times \frac{10}{3} =)$ 23.3d. for the 40 minutes' work.

Objections, however, had been raised to these systems. One was that no bonus was paid until the task rate was reached, and another was that there was too much profit to the employers. There had also been objections by the trade unions to these systems that they destroyed the principle of collective bargaining of the trades union organisation, that they encouraged scamping of work and accidents, that they promoted workshop selfishness, led to unemployment, and prevented the training of apprentices.

Payment of Wages.

With regard to the special system of a piece rate and bonus rate to which he referred in his first lecture, it was a little complicated, and he did not understand precisely the principle on which it worked. The employer of this system, however, said he had tried the others and found his own was fairer to both the employer and the employee. Under it the men were first trained, and whilst they were being trained they were paid 25 per cent. above the district rate. A standard output was set, and as soon as a man could reach it, then he began earning on the scale of the special system and the working hours were reduced from 54 to 48. As soon as a 60 per cent. standard was reached, the following formula was used, $\frac{PR-X}{2H}$ where PR represented piece rate, H the number of hours of work and X a base rate of x pence per hour, whatever it might be. The result of the equation was added to the piece rate in the form of a bonus. It was claimed for this system that the bonus automatically increased with increased output and with good timing.

The Day Rate.

The last system he would mention was the day rate, and he thought that there was no doubt that the mass of workers were in favour of that. It made no differentiation between good and indifferent workers and therefore tended unfortunately to a standard of mediocre uniformity in output and quality of production. The question was how was it possible under such a system to recognise individual differences in ability and to induce each worker to do his best. There could be no doubt that human nature as it was at present constituted required incentives to work besides duty. The piece rate must be a worry to the worker, who, when he was a little "off colour" and could not work so well, knew that those dependent upon him would suffer by his indisposition. Dr. Myers believed that as work became less and less mechanical, and more and more skilled every year, we should ultimately adopt some form of day rate, and abandon the piece rate system, which assumed the workman to be a piece of machinery, revolving so many times a minute, and capable of revolving faster with the prospect of increased earnings. He did not think there could be any doubt that the piece rate, advantageous as it was from the point of view of output, would give way in time to the day rate.

That was the conclusion he had arrived at, but if they had a day rate it must be combined with some form of graduation of pay according to individual efficiency. He had been informed that there was already one trade union in which men were graded according to ability, and if a man considered he ought to be in a higher grade he applied to the employer. Should the employer not agree the man could appeal to his union for an examination, and if the man failed he paid the fee, whereas if he passed the examination the employer paid the fee. He did not, however, know what truth there was in this.

Lastly, he came to the great question of the education of the employers, who had much to learn in regard to their relation with their employees, and of the education of the employees, and their trade unions too. There was no doubt that a very large proportion of previous industrial unrest had been due to want of knowledge, to want of sympathy, and even to hatred between capital and labour. There had been a long-standing policy of rival "grab" between the two. Hatred, of course, was very difficult to eradicate. Someone had once said, "I cannot hate a man when once I know him," and there was a great deal in that. If only one knew intimately enough the people whom one hated, it would be found very difficult to continue the hate. The abolition of what might be called the "absentee" employer, the introduction of some measure of "Home Rule" in the factory and the spread of technical education and knowledge of industrial aims among the workers would do much to improve the relations between capital and labour. Collective bargaining, which was claimed as an essential function of the trade unions, would ultimately be needless. There should be definite principles laid down as to the maximum profits of capital and the minimum wages of labour, the term "labour" being here used in its broadest sense so as to include the labour of direction and research by brain and the labour of production by hand. There would, of course, be plenty of work for the trade unions to do, even after their present work had been to a large extent transferred to Whitley Councils, workshop committees, and the like. The unions would still have to help the weak and defenceless, and to ensure proper standards of comfort and rest. It would be their duty to aid in improving efficiency and to assist investigations into the best conditions for the best work with the least fatigue.

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LONG observation in a corrugated iron factory in America shows that, on the average, about 350 square feet can be covered with a gallon of paint when it is applied by an air sprayer.

MESSRS. J. SAMUEL WHITE & CO., LTD., East Cowes, Isle of Wight, have secured the contract to construct 12 steel barges of 200 tons capacity for Messrs. William Cory and Son.

Frank Bunker Gilbreth.

The Man and His Work.

ON another page we print a communication from Major Frank B. Gilbreth, E.R.C., U.S. Army, which merits special attention (upon the old homestead of his family, Bunker Hill is situated, hence the reason for his second christian name). The work of Major Gilbreth has achieved world-wide fame, but it is doubtful whether it is as well known in this country as it deserves to be.

Born in 1868, Gilbreth completed his formal education with graduation from the English High School of Boston in 1885, went into business, and in the course of time became established as a successful contracting engineer engaged in large scale undertakings, and rapidly became known as the "lightning contractor." From 1885 he was constantly thinking in terms of "motions," and invented appliances for making short cuts. In 1892 he was given a silver medal for his travelling scaffold. In 1897 his portable gravity concrete mixer was invented. It was a great invention and by its means contractors were enabled to undertake profitable jobs at sixpence per yard. In 1896 Dr. Taylor's lieutenant, Mr. Sanford Thompson, first timed his building operations. In 1904–5 he invented the Fountain trowel. In 1907 he first met Dr. Taylor, and learned from him certain facts, viz., that the economic lifting load was 92 lbs., that of a loaded shovel $21\frac{1}{2}$ lbs.; more accurate prophecy in the amount of work a man could do, by timing the work periods and the rest periods separately; the details of the task form of management; super functionalisation and standardisation; and the differential rate piece work system. All Gilbreth's established standards had been in writing since 1897, and were amplified and modified after these conferences, and a study of Taylor's papers on "Shop Management" and the "Art of Cutting Metals." His first attempts in the application of Taylor's methods were then begun, with the happy results all the world now knows. This consisted in a reorganisation of bricklaying, an undertaking whose brilliant execution was to win for him a national reputation and to constitute with his later work one of the most fascinating chapters in the history of scientific management.

Gilbreth, following in the footsteps of all other scientific management leaders, incorporated in his fully developed bricklaying system an ingenious provision by which the number of bricks laid by each man might easily be calculated; he provided that those individuals who should come up to a certain high standard should receive wages 25 or 30 per cent. higher than the wages common among other bricklayers in the vicinity.

Dr. Horace B. Drury has truly pointed out that the real emphasis in Gilbreth's scientific management, and that which from first to last has given to it its distinctive note, is on constructive motion study—that is, the scientific analysis of the motions that go into work with the idea of eliminating avoidable effort. The original object of Taylor and others was to discover how much men could do if they tried, and their development of new methods of work, though important, was incidental. In the case of Gilbreth, however, it would be more fitting to say that he started out in the first place with the object of devising new and better methods, and that his introduction of management features like the task and bonus was chiefly to secure the carrying out of directions.

To present some of the more salient motion and fatigue-saving features of the Gilbreth system of bricklaying, it may be noted, in the first place, that the obvious waste of making a man bend over, and then raise the weight of his body, every time he has to pick up a brick a thousand times or more a day—was eliminated by arranging adjustable scaffolds and so piling up the bricks that there would be between the body of the workman, the height of the wall, and the height of the brick supply and mortar box just that relation which would permit the easiest, most upright work. In the second place, there was taken away from the high priced bricklayers and turned over to low-priced labourers the simple work of arranging the bricks with their top-sides up. Gilbreth tells us that the top of a hand-made brick is always a little wider and rougher than the bottom, and that under ordinary systems the bricklayer "flops" each brick over in his hand a time or two to make sure which is the right side. This operation was eliminated under the new system, for the bricks were properly arranged by the low-priced helpers on "packets" holding eighteen each, so that they might be easily grabbed by the craftsman and inserted without examination into the wall. Thirdly, it may be noted that the mortar was tempered so carefully that the bricks could be thrust into place by a simple shove and without the usual tap of the trowel.

In the above, as well as in many other ways, the work of bricklaying was so simplified that the eighteen motions formerly thought necessary to place a brick were reduced to four and a half, and indeed in one case to two. Those which remained were made as simple and effective as thorough study could make them. The final result was that Gilbreth's men, who had formerly worked to their limit to lay a 1,000 bricks per day, were able after a short period of instruction to reach a daily output of 2,700. Gilbreth erected a number of buildings in accordance with this plan, and still holds patents covering several of the mechanical features.

Not long after the perfection of the system, however, its inventor abandoned the contracting business altogether, and began to turn his entire energy towards introducing scientific management into factories. The best example of what Gilbreth has accomplished along this new line is stated by Dr. Drury to be afforded by the New England Butt Company, a concern which is engaged in the manufacture of braiding machinery, at Providence, Rhode Island. The system there installed may be said to be patterned after that in use in the plant of the Tabor Manufacturing Company, differing from the latter chiefly in the greater attention that has been given to contriving many small conveniences which lighten the work. We [illegible] therefore, not describe Gilbreth's methods in detail, but will present only those features which are [illegible] own distinct contribution to management technique. He has made two notable contributions, of which the first is micromotion study.

Prior to the introduction of micromotion study, the best instrument available for making time motions was the stop-watch. But there is a